Usability Requirements for Collaborative Environments

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The current growth in video conferencing systems and tele-education applications is heralding a shift in the nature of Human Computer Interaction. The growth of new media technologies such as digital television, and the WWW is increasingly becoming a part of everyday communication and entertainment amongst individuals. These new interactive systems are likely to be accompanied by a need for a new model of design centered around user needs within participatory environments. As Paul Dourish [Dourish, 40] suggests, these new models of computer usage require an accompanying shift in the structure of the systems that are built. It is the intention of this study to examine this situation and to attempt to identify the requirements for delivering effective collaborative conferencing tools within corporate and educational environments.

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1.0 **Collaborative Environment Design**

1.1 Executive Summary

The following report is a usability requirements analysis of current internet conferencing tools, being developed and delivered under the MECCANO project. In order to facilitate this, the report attempts to provide an overview of the current state and usability of desktop conferencing systems. It outlines the basic issues and requirement for these systems and undertakes an evaluation of different approaches to delivering conferencing solutions.

In general the conclusion of the report is that the primary usability limitation in the current toolset lies in the underlying Mbone network which supports the tools. As IP Multicasting is relatively young the performance and reliability of IP enabled networks is unable to effectively support the type of ubiquitous access to the conferencing infrastructure that is ideally sought. This issue has been the only significant limitation to using the tools. The core conferencing tools developed by the MECCANO partners implement the primary requirements for delivering usable and flexible conferences. The tools are stable, relatively intuitive to use and address the basic requirements for delivering effective desktop conferencing scenarios at an application level. Yet they are hindered in their overall functionality by the limitations of the underlying network on which they need to run. This would therefore indicate that a large part of the actual usability, and acceptance of the tools will depend on the eventual resolution of current networking limitations and either the expansion of IP multicast enabled networks to the level of current unicast networks, or the development and implementation of unicast/multicast gateways. As is outlined in section 2.3.12 and section 3.2 there are currently approaches within the MECCANO project being developed which provide these gateways solutions.

For a more detailed description of the multicast architecture, and the steps being taken to resolve multicast/unicast connectivity see the MECCANO architecture paper at Http://www-mice.cs.ucl.ac.uk/multimedia/projects/meccano/deliverables/

1.2 Introduction

As Schooler [Schooler, 483] points out the growing convergence of computer, television and telephone technologies, has given rise to new styles of communications. The interactions between people that were once supported using several different technologies over several disparate networks are beginning to be integrated within one framework [Schooler, 483]. As the Internet, and computer network technologies in general continue to develop and expand we are seeing a parallel growth in the use of the computer as a tool for mediating communication between individuals and groups. As the deployment of collaborative programs and educational tool sets increase, there will be a corresponding increase in users who have little or no knowledge of Internet protocols, compression schemes or conferencing scenarios. The willingness to adopt these technologies will become increasingly dependent on the transparency of their usage. This is particularly acute in education scenarios where as Hall [Hall, 376] points out, although there is considerable potential for the use of collaborative multimedia systems, they are not yet part of the everyday culture of learning and teaching in higher education. Current networking limitations, and the lack of effective tools are part of the reason for this situation. However the usually steep learning curve required to change the methods of delivery of educational material, and to adapt to the usage of new tools, as well the hesitancy to abandon traditional approaches to education are perhaps the most significant factors hindering the development of tele-educational tools [Hall, 376]. These reasons are also applicable to the relatively slow adaptation of collaborative conferencing tools in corporate environments. It is the intention of this study to examine this situation and to attempt to identify the requirements for delivering effective collaborative conferencing tools within corporate and educational environments.

1.3 Collaborative Environment Design

The current growth in video conferencing systems and tele-education applications is heralding a shift in the nature of IT and subsequently Human Computer Interaction. The added growth of new media technologies such as digital television, and the WWW is increasingly becoming a part of everyday communication and entertainment amongst individuals. This, as would be expected, is causing a shift in the model of computer usage from an essentially task based model, to one which encompasses a communication and media delivery model as well. These new interactive systems are likely to be accompanied by a need for a new model of design centered around user needs within participatory environments. As Paul Dourish [Dourish, 40] suggests, these new models of computer usage require an accompanying shift in the structure of the systems that are built. Limitations in the implementation of traditional models of HCI tend to become apparent when system are required to be designed which consist of less discreetly defined tasks or the user is required to interact with information delivery systems such as multimedia presentations.

As Shneiderman [Shneiderman, 481] points out, developing cooperative environments is a difficult challenge because of the numerous and subtle requirements of effectively recreating natural communication patterns. These patterns, which are crucial for effective work and learning procedures have proven difficult to capture over video and audio communication channels. Further effective research into this area is typically more difficult than that required for single user interfaces. The multiplicity of users which need to be observed makes it difficult to gather controlled experiments and obtain reliable and orderly results [Shneiderman, 480]. Secondly the lack of clearly definable task goals make it difficult to obtain quantitative assessments of the effectiveness of the specific tools being tested. Traditionally HCI design has relied on presenting users with specific tasks to accomplish and then measure how quickly or efficiently they accomplish those tasks using different interfaces. In collaborative scenarios, where discrete goal based tasks are not the objective, measuring the effectiveness of a system becomes more difficult. This points out one of the central issues of communication based application development. Because the rational for interacting with the computer is different from traditional program usage, it would seem that new approaches to designing and testing these applications are required. Typically, therefore user studies of this area have largely relied on subjective reports and case studies to attempt to determine the relative success or failure of the groupware applications being tested.

1.3 Scope of the study

The study will proceed from a basic investigation of current collaborative tools. This investigation will be based on an analysis of the usability of the desktop conferencing tool set developed under the MECCANO project. Within this framework the study will discuss the general usability requirements of video conferencing tools, discuss their potential uses, and identifying their current strengths and limitations. It is also the intention of this study to identify areas for further work and potential implementation for the tools, and proceed to an outline of areas for investigation in the development of next generation collaborative environments. This will be particularly considered in the context of the delivery of tele-educational systems.

2 Overview of Video Conferencing

2.1 Background

While the interest in Video conferencing systems has been around since the sixties, it was not until the early 1980's and 1990s that there was a large growth in the use of Video conferencing systems. These systems were typically room based and consisted of cameras and video monitors installed in special meeting rooms which are linked together by circuit based telephone lines and more commonly ISDN connections[Patrick, 6]. This scenario involved the installation of special equipment to control and transmit the various media streams. While there was a belief that these systems would allow people to communicate over vast distances and thereby reduce the need for travel, room based video conferencing systems did not prove very successful [Patrick, 6]. There were a number of reasons for this, the equipment was expensive and lacked standardization, was often difficult to use, and required tightly controlled conferencing scenarios. The systems also required special connections to operate and needed dedicated people to administer them [Patrick, 6]. A particular disadvantage of these systems was the poor facilities, often non existent for sharing documents and data, which hindered their usefulness for collaborative work.

Subsequently the recent increases in the development of desktop computers, and the growth of the Internet has been seen as a frameworks for developing collaborative applications which will over come some of the limitations of ISDN based conferencing systems [Patrick, 6, Schooler, 484]. The desktop computer has the advantage of being convenient for most people to access, with widespread home and office usage. The increased access of home and office computers to a global networks provide users with the potential to quickly access conferencing tools and sessions, within the context of their daily activities. While the desirability of this and the potential benefits are obvious, the actual realization of this still appears some way off, with several issues remaining to be sufficiently addressed both in terms of human factors, and the underlying technology supporting desktop conferencing systems.

The following section will give an overview of some of the obstacles hindering desktop conferencing systems It will then attempt to address some of the possible solutions. While it discusses to a small extent the architecture of the tools, this is not the main focus of the paper and is only discussed to provide a context for the consideration of the human factors aspect of collaborative environments. For a more thorough and detailed discussion of the various architectural approaches to delivering multimedia enabled conferencing see the Mecccano website at http://www-mice.cs.ucl.ac.uk/multimedia/projects/Meccano/. This site contains information about the Meccano project and the tools it is developing. These tools, which are discussed below are also available at their website. The site also contains useful links to additional information on IP Multicasting, and other related projects being undertaken at University College London.

2.1 Architectural models for collaborative computing.

Schooler [Schooler, 489] has identified there types of architecture models used in the development of collaborative environments.

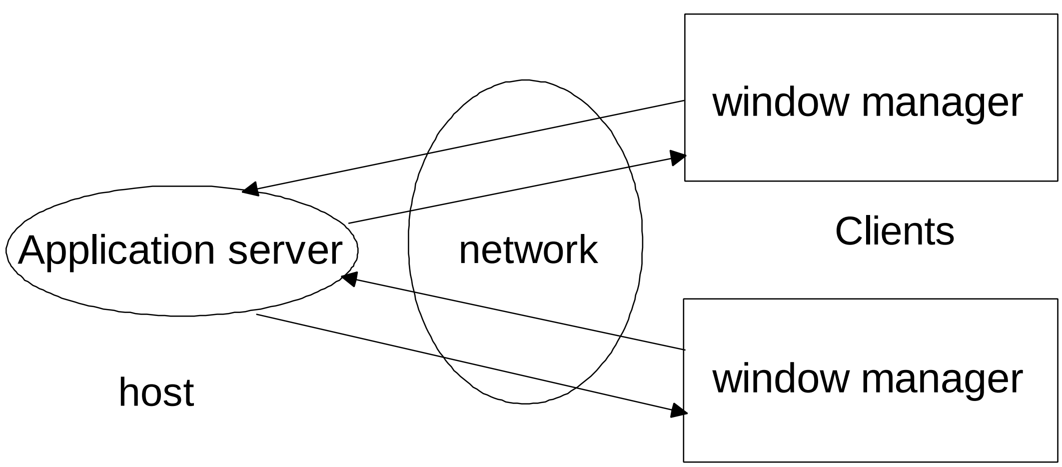
1. a centralized model.
2. a replicated model.
3. a hybrid model.

2.1.2 Centralized Model

A centralized model executes the application at a single site. Input from the site which maintains the floor is forwarded to the applications location and is broadcast from the application to the other participant sites.

A primary advantage of this model is that it:

1. Allows for tighter floor control policies and potentially easier establishment of secure conferencing sessions. Because all conferencing traffic is controlled by the central server it has the facitility to monitor and tightly control the flow of that traffic. For instance the Placeware conferencing system developed by Placeware Inc. allows a very tight session control policy, and enables members to request control of the floor, or to initiate private conversations between each other. It also enables multilevel access control of the conferencing sessions. This enables specific users to be granted or denied access to specific sessions.
2. Allows for a potentially easy integration of single user applications into group orientated scenarios [Schooler, 490]. Typical applications which benefit from this model are educational collaborative systems, such as the HP virtual classroom and Placewares conferencing system. These systems rely on a central server to control and generate the client application for the conference. When a user logs onto the system to take a course, or participate in a conference, a Java based client is launched through the users browser window. The control of the environment and delivery of material is initially handled by the central application which forwards content to the participating sites. Because documents such as Powerpoint files can be uploaded to the central server. It is able to implement tight revision control policies on that



document, monitoring and archive changes to the document..

The disadvantages of a centralized model are:

1. Limitations in scalability and venue agility. Typically server based conferencing systems are designed to suit specific scenarios and are not easily adaptable for usage in other scenarios. The Placeware application for instance, while it can be used for delivering either educational

scenarios, or telephone style conferencing, does not enable the use of an interactive video channel. It is therefore well suited for pre recorded seminar and lecture style scenarios where the ability to visually see the presenter is desirable, but not well suited to scenario in which a two or multi way interactive discussion between participants is necessary, such a language learning scenario.

2. Difficulty supporting display policies other than what you see is what I see [Schooler, 489]. If only one copy of an application runs, as it would in a centralized approach, with output duplicated to all sites through a client application, then the receiving sites must display what is generated from the central application. This results in a limitation of an individual users ability to tailor the workspace to their personal needs.

3. Potentially poor interactive response due to the heavier level of network traffic they generate [Schooler, 489]. Because traffic is typically routed through a central source this can create potential bottlenecks in the traffic flow, and introduce delays into the conferencing interaction. This introduces limitations to real time multimodal interactions between participants.

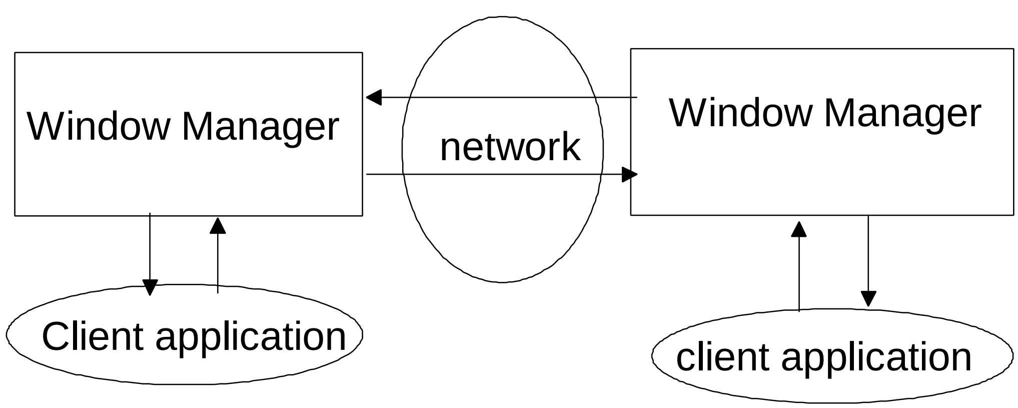
2.1.2 Fully Replicated model.

In a fully replicated model each site in the conference runs its own copy of the application. In this model the site which maintains control over the floor, broadcasts its output to the other participating sites. The output in this scenario is generated locally at each site, and control of the floor can rotate between the various participating sites. Each member of a conference then runs the conferencing tools from their own computer. This model forms the basis for the Meccano Mbone tools (although there are client server model aspects within the MECCANO project).

The disadvantages of a replicated architecture are

1. They typically require each site to have its own copy of all files, whether they are data or executable programs that are being shared [Schooler, 491].

2. They need to avoid operations that are dependent on synchronizing the timing of input,



such as holding down a mouse key to scroll a window. Etc. Environments like the Internet which may at times introduce highly variable delays or routing failures that create brief service outages, can create problems in the synchronization of data [Schooler, 490].

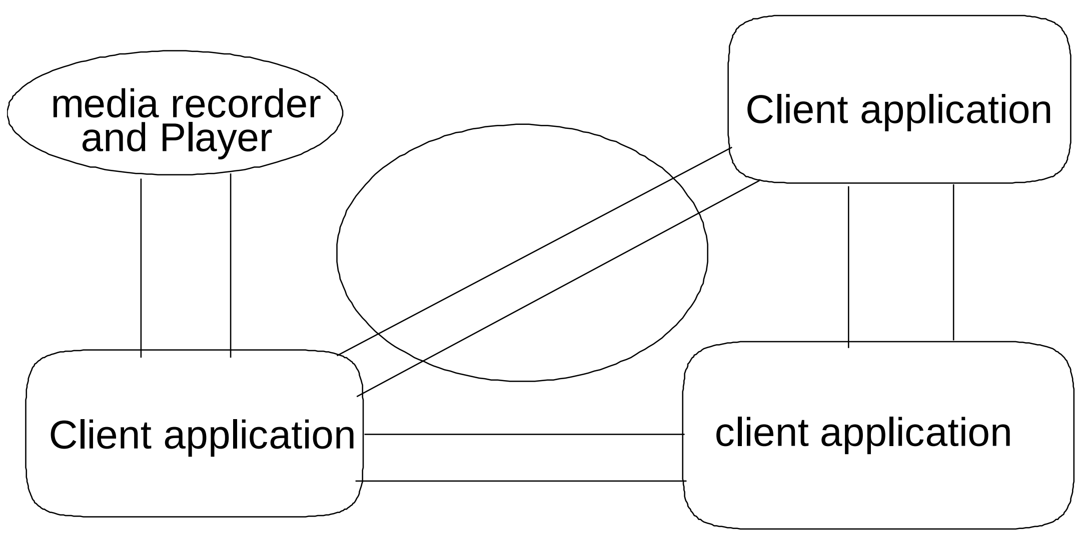
3. Replicated architectures generally have a greater difficulty addressing file distribution, synchronization. Because there are multiple copies of shared documents, or programs,

distributed amongst the clients it creates a greater challenge to track and maintain a consistent state between all the objects in the group.

The advantages of a replicated architecture is that they:
1. Typically provide quicker response times to participant interaction. Because of the greater efficiency of data distribution replicated architectures are less prone to delays in the communication channels. Especially in geographically distributed environments.
2. In multicast solutions they tend to impose less of a load on the network then centralized approaches [Schooler, 496].
3. Are more flexible and responsive to varying network conditions.
4. Enables a more casual floor control policy, which can be an advantage in brainstorming type conferences, where spontaneous responses and interjection are crucial.

In general replicated architectures have achieved a larger acceptance for developing conferencing tools due to the easier implementation of the tools, and their greater flexibility then centralized approaches [Schooler, 489]. The advantages of this are especially evident in a Multicasting scenario which create a much more efficient usage of network resources than a unicast model.

2.1.3 Hybrid Model
A Hybrid approach attempts to mix the best of these schemes, such as maintaining data consistency through a centralized data store, but supporting individualized views through the use of replicated graphical front ends, which each participant can have control over



Typically a hybrid approach may operate over a multicast network with each user operating their own version of the tools. Such a system may maintain the replicated model of media stream distribution, but contain some mechanism, such as a server in the conferencing chain, for controlling shared documents, or archived media such as previously recorded sessions. Such a system would have the advantage of providing a centralized store for conference sessions without having to control each instance of the client application participating in the session.

2.2 IP Multicasting Overview

The bulk of this study is concerned with an assessment of conferencing tools using Internet based networking, especially the multicast enabled part of the Internet network called the Mbone. Currently the Mbone is in an early stage of development and is mainly used for conferencing and the distribution of multimedia broadcasting. While there are other infrastructures for teleconferencing such as circuit based ISDN networks, the Internet and especially the Mbone are increasingly becoming the focus of development for the delivery of conferencing applications [Patrick, 12].

One of the limitations with ISDN based conferencing is that it does not scale as well as multicast solutions [Kirstein, et. al. 5]. Further it tends to require tightly controlled, conferencing scenarios and specially set up rooms. IP Multicast on the other hand, can provide a more casual implementation model, can be set up to run from any desktop computer, and is able to provide a more efficient many-to-many distribution of data [Kirstein, et, al. 5]. It also avoids the need to configure special-purpose servers to support the session. The use of a centralised server based approach, such as that used by some IP unicast models, requires additional support, and can cause traffic concentration and bottlenecks. For larger broadcast-style sessions, "it is essential that data-replication is carried out in a way that requires only that per-receiver network-state is local to each receiver, and that data-replication occurs within the network" [Kirstein, et, al. 4]. IP Multicasting is able to offer greater efficiency because data is replicated in the network at appropriate points rather than in the end-systems.

From a usability perspective the replicated, multicast approach offers several advantages. One is that it requires no specific support to start and stop conferencing sessions. Any individual with access to the Mbone and the multicast tool, can initiate a conferencing session, set up a seminar, or establish and educational based sessions. Sessions can be quickly and easily set up and closed. It does not require any special rooms to be set up or any additional hardware other than a desktop computer. The primary advantage however is in the improved traffic routing structure. For proper real time interaction it is necessary that as close to zero delay in the communication channel as possible is achieve. For this reason the Multicast approach is a more practical solution for multi-party conferencing then IP unicast, or ITU solutions.

2.0 Usability Requirements for Collaborative Environments

2.1 Introduction

Building collaborative environments is complex and has a large number of issues which must be taken into account when developing systems and tools. Patrick (Patrick, 15) suggests that a useful approach to studying video conferencing is to delineated it into three parameters: the task of the session, the media used, and the communication modes involved. Patrick maintains that these parameters help define a human factors space for video conferencing where the location a particular scenario may inhabit in the space indicates the specific demands and requirements on the technology and the users [Patrick, 15]. The extent to which a specific scenario encompasses the parmeters in this model will ultimately determine which tools are employed and the nature of their implementation. In delivering an education session for instance the user will need to determine exactly what features in this space they need to implement and what tools or approach will best satisfy these requirements. This however requires an understanding of the basic requirements for building collaborative environments.

Various research, [Schooler,483, Rada, 551, Barua, 1760] into user interaction within collaborative environments has identified a number of issues which are common across a range of collaborative scenarios. These issues indicate generalized requirements for identifying the functionality which a collaborative environment should be able to deliver in order to successfully appeal to a broad base of users.

1. Flexible Geographical scope.
2. Multimedia content delivery.
3. Real time interactions.
4. Multi modal communication.
5. Floor Control.
6. Scalability.
7. Venue Agility.
8. Session Security.
9. Session Recording.

These are of course generic aspects and may not actually indicate requirements that every implementation of a collaborative environment has to address. While collaborative scenarios exist for instance in which real time communications, session security, or the ability to record a session, may not be necessary, it should be assumed that these features are available as a basic functionality within the framework that is delivering the collaborative environment. It is the intention of the following section therefore to provide an overview of the key above issues and requirements for delivering usable collaborative environments. This will be discussed within the context of the MECCANO tools.

2.2.0 Flexible Geographical Scope

Flexible geographical scope is the ability to encompass a varying geographical range in the delivery of collaborative interactions [Barua, 1762]. In short an effective collaborative environment should be able to encompass a global scope as easily as a local scope for the range of its transmission. More importantly it should be able to explicitly set the range of the scope which it intends to encompass. Currently the MECCANO toolset enables users to set the range of their transmissions to local, regional, international, and world wide scope. This

helps to insure an efficient use of network bandwidth, and to enable a loose control over the extent to which individuals can access the conference. If for instance a seminar is set up to be multicast and the intended audience are known to be within a local area network, then it would be desirable to limit the range of the multicast to the LAN. This prevents the flooding of the Multicast network outside the LAN with unnecessary traffic.
Within the MECCANO tools there are two methods for controlling the scope of a conference, Time to Live and Admin scope.

2.2.1 Time To Live

(TTL) determines how far the audio and video that a user transmits will travel [Clark, 12]. A TTL of 15 will reach other parts of a LAN, a TTL of 47 will extend to a national part of the Mbone, a TTL of 63 will reach an international range and a TTL of 127 will reach worldwide. The default setting for the Mbone tools is a TTL of 16. The Exact Scope of a TTL typically needs to be set up and controlled by the network administrators. Currently TTL is still the most common scoping method in use.

2.2.1.2 Admin scope

An alternative method of defining the geographical scope of a session is Admin scope. Admin scope is intended to eventually replace TTL. An Admin scope provides a greater accuracy in limiting Mbone transmissions and is more sophisticated than using a TTL. Admin scope also needs to be set up by the network administrator. Admin scopes work by having a range of addresses defined by the network administrator. Specifying an address in the range set by the administrator provided will limit the conference to that range. [Clark, 12]

The scope a session will reach is determined through SDR when the session is announced. This is accomplished through SDR when setting up and announcing a session. This is trivial to accomplish with SDR and contains enough flexibility to satisfy most session types.

In terms however of accessablitly there are a number of related difficulties which limit the usability of all multicast conferencing tools.

2.2.2 Firewall restrictions

A related issue affecting accessibility is that of using collaborative multicast enabled applications from behind firewalls. Currently applications which rely on multicasting, such as the MECCANO tools, as well as other conferencing applications like Netmeeting are unable to transmit through firewalls. For corporations, or institutes which use firewalls this realistically constrains the options to unicast solution for conferencing such as the Placeware application which uses a combination of java applets and phone calls to set up conferencing scenarios. While this is a workable solution, it lacks the flexibility and performance advantage of a multicast solution such as the Meccano tools. This is perhaps the greatest hindrance to current conferencing tools in that it places a restriction on the range of their usage. Either users must have an unrestricted connection to external, multicast networks or they are unable to use the tools outside their LAN. In order for Multicast based solutions to be truly usable this problem will need to be overcome. Currently solutions to this are being investigated within the MECCANO project. For more information on this see the joint MECCANO paper Multicast and Firewall: comparison of two possible solutions at http://www-iri.hpl.hp.com

2.2.3 IP Multicast support

A similar limitation for the current tools is the lack of broad based support in the Internet Network for IP Multicasting. One highly advantageous usage of multicast conferencing would be the ability for a user who is away from the office to be able to join a conference from their laptop connected to a hotel phone line. This sort of ubiquitous access to collaborative environments is one of the most enticing aspects of the technology. Currently users working from home, or mobile users are unable to connect to the Mbone, as few ISP's offer multicast enabled routers, or Gateways. While this situation is changing, and multicast connections are becoming more available, it still currently places a restriction on the use of collaborative tools. Currently the MECCANO project has or is developing various Gateways, and reflectors to broaden the accessablity of the core tools.

2.2.3.2 Unicast Gateways

As discussed in section current gateway tools such as UTG, Stargate or Multicast-unicast reflector are being developed which would enable the delivery of multicast session to members on or across unicast connections [Kierstien et, al. 33]. These approaches vary in the exact nature of their implementation but generally consist of some sort of a control engine which joins the multicast groups and maps the traffic to the unicast based host. The client application consists of an additional application to the basic media tools. The limitations of this approach is that it is yet to be widely implemented and is still not as ideal a solution as users having direct access to multicast networks. However as it is likely that such widespread access to multicast networks is not an immediate likelihood the use of a Unicast Gateway such as UTG appears to offer the most, efficient solution to this problem.

2.2.3 HTTP based unicast conferencing.

An another solution to delivering multi-particpant conferencing is that offered by centralized HTTP based solutions such as Placeware. This is a server based conferencing application which uses a combination of Java technology and dial up phone connections to establish a conference. This approach has the advantage of encompassing an essentially unlimited user base. Effectively anyone with a web browser, an Internet connection and a phone line can log onto a conference session whether they are at home, or behind a firewall. However this is limited by an inability to deliver video, and the requirement of having a phone connection separate from the Internet connection in order to participate in audio conferences. As is discussed in more detail below, the presence of a video channel can increase the effectiveness of conferencing scenarios, and of educational applications. Most importantly however, the implementation of a server based HTTP approach requires a more formalized conferencing structure. While this may be useful for educational scenarios, or formalized seminars, and conferences it is unable to deliver as comprehensive a range of features as Multicast conferencing.

2.3 Multimedia content delivery

While it may be a given, that collaborative applications deliver interactions which encompass and make use of audio, video and textual media the support for Multimedia content extends beyond the needs of a basic video conferencign system. A flexible collaborative framework should be able to deliver both asynchronous and synchronous media elements in an integrated and interactive manner [Barua, 1762]. In a multimedia rich system facilities would exist to support textual material, pictures, charts, voice and video images in a a manner which allows the co-ordination and integration of the media. While this would seem a basic functional requirement of collaborative environments, there are a number issues related to the delivery of multimedia interactions which are worth considering. The most obvious is the demands it places on network bandwidth especially in WAN's such as the Internet. Current difficulties with most conferencing systems arise from limitation in this area which have hindered their adaptation on a large scale.

Conversely text based systems receive a fair amount of use and are growing in popularity among home based users [Barua, 1762]. This is due in large part to their ease of use and the ability for users to interact with each other in a intuitive, and non intrusive manner. There is little lag in the communication channel, and while the communication is purely text based, it is as efficient, and generally faster as any other form of text based communication, and has some significant advantages over other forms of text based communication methods such as faxes, and letters (rapidity of response, informal structure, etc.). This is perhaps the key to its success, in that it is at least as good as or better than the alternative. As the amount of media richness a system tries to introduce climbs, so does the amount of network load, and potential delays in traffic delivery. In addition difficulties in designing the systems also increases. This is particularly evident in the Internet where the delivery of media rich interaction is introducing ever increasing delays in accessing the information users wish.

However the demand by users for more media rich interaction than those available through text based application is clear, and continues to grow. While the increase in media rich interactions has made accessing web sites, more difficult, the promise of media rich interactions is also fueling the interest in technologies such as netmeeting, Real video, and the MECCANO tools. It is clear therefore that the ability to deliver media rich collaborative systems is a necessity. Particularly since the primary demand for Media Rich systems is the need to capture the subtleties of pitch, tone etc. which are part of face to face communication. While text based collaborative systems are effective for casual communications, more formal, or critical communications require more personal communication afforded by face to face interactions.

Currently the MECCANO tools are particularly adept at accomplishing this task. The media tools Vic, Rat and Rendezvous are the primary tools for delivering video and audio content. In typical network conditions Vic is capable of delivering video frame rates of between 6- 8 frames per second. Rat performs even better in delivering audio, generally achieving rates which make interactions between participants reasonably efficient. While it lacks the rapidity of vocal response as current telephone lines this is due largely to limitations within the network , rather than with Rat itself.

The secondary case for insuring the delivery of interactive multimedia content is in the use of multimedia presentation material for live seminars, recorded sessions, or multimedia applications. In a conferencing scenario these may be less of a necessity, but for educational scenarios the ability to deliver a range of multimedia content would almost be a necessity. This requires the ability to control the media, and include some form of interactive ability into the media stream. A typical scenario may be one in which a tutor wishes to deliver a video of some event which they can control and comment upon during its playback. In this context the ability to integrate and control the timing between the various tools would enable the synchronization of the various media elements. This would allow teachers to potentially create an integrated media rich presentation which could coordinate the events occurring between the various media streams. This would also be an advantage in presentation and seminar scenarios

Delivering multimedia material however also requires flexibility in determining the appropriateness of media rich material for specific scenarios. In the delivery of multimedia educational material, or collaborative working scenarios for instance, it may be desirable to limit the level of media richness, in order to dedicate resources to other tasks, or in order to more effectively accomplish certain tasks. In the MECCANO tools for instance individual members of a meeting can choose whether they wish to transmit video, audio, or to join a session using simply the text editor, or shared whiteboard. This allows users on more bandwidth restricted connections, such as modems or ISDN lines, to select less bandwidth demanding tools to participate in the conference.

2.4 Real time Communication

Collaborative environments should naturally be able to deliver real time interaction between participants and their access to documents. Real time communication is essential because collaboration in groups typically depends on immediate input and feedback in order to be effective. While one of the primary limitations for delivering real-time media rich interaction has been network bandwidth this has not been a problem within Lan environments, yet the adaptation of collaborative tools in these environments has not been significantly quicker than that in WANs such as the Internet [Barua et. al., 1767]. This is largely due to the problem of integrating disparate functions such as document processors, messaging systems and group activity monitoring. These currently present the biggest challenge to collaborative environments. As the range of media which is incorporated in collaborative environments increases it becomes necessary to insure that synchronization schemes are developed. In general realtime interactions depend not just on fast network speeds but on adequate synchronization mechanisms between the applications [Schooler, 500]. User interfaces, group processes and con currency control are key features which need to be considered in order to aid group editing, document sharing, and real time interactions. [Ellis, Giggs and Rein, 1991].

The most apparent need for synchronization is between the audio and the video streams. In order to enable natural communication patterns it is necessary for the audio to be synchronized with the video channel so that communication appears natural. Currently the MECCANO tools are able to ensure that this occurs reasonably well, and the interaction between participants is only hindered by the low frame rate for the video channel, and camera placement restrictions, which makes eye contact difficult.

A further difficulty is the lag in transmission of audio and video which causes problems with interpersonal interactions. In an informal communication session individuals rely heavily on instantaneous response to determine whether it is appropriate to interrupt the current speaker, or to initiate conversation. While the Meccano tools attempt to compensate for this situation by synchronizing the video and audio channels, response time is still not sufficient to enable unrestricted real time interactions. However the severity of this situation is related to the scenario for which the tools are being implemented. In more controlled interaction such as the transmission of educational material, where interaction between individuals tends to be governed by stricter social protocols, the tools have proven to be sufficient to deliver usable interactions between participants. This is also the case with seminar scenarios, where a single speaker tends to hold the floor, with other users listening to the talk, and later responding in a question and answer sessions. Because these sessions are tightly controlled, the interactions are more easily controlled and therefore sessions tend to be more successful.

While there are some minor hindrances to real time interaction over the video and audio channels, it is less of a problem with the NTE and WBD the shared whiteboard and text editor. The interaction responses between these applications is typically sufficient to enable highly usable collaborations between individuals. The shared whiteboard for instance provides highly usable near real-time interactions allowing sufficiently rapid feedback to user input. Edits to the whiteboards appear quickly, which is necessary to enable proper interactions.

2.5 Floor control

There are a number of reasons for insuring adequate control over user access within a multiuser environments

1. To control interactions procedures in large scale collaboration situations. In a seminar setting for example it would be necessary to control viewers feed back in order not to interrupt speakers and to control interactions during question and answer sessions.
2. To prevent users from accidentally making changes to shared documents that may be difficult or costly to correct.
3. To prevent violation of security constraints preventing users from accessing documents and sessions they are not entitled to access. A group for example in an educational environment may need access to differing sections of a document. It would be necessary in this situation to prevent students from sharing this document amongst themselves or collaborating with each other while the document is open.
4. To limit inappropriate usage of resources that are constrained by bandwidth.

Deqan and Shen have identified a general framework for defining access control in single user and multiuser interfaces.

1. Generality: It should support arbitrary applications.
2. Total mediation Every access to every object should be checked for current authority. [Galtzer, 1974]
3. Least Privilege flexibility . Every application and every user should operate using the least amount of privilege necessary to complete the job. This is also called the need to know principle. This principle implies that the framework should be flexible i.e. It should support arbitrary access control policies. [Galtzer, 1974]
4. Ease of use/ high level: It should be easy to specify these policies. This principle implies that the framework should be high level. It should require few specifications to identify the desired policy.
5. Efficiency. The cost of storing , modifying and checking access specifications should be low.

Currently most desktop conferencing systems give all users the same rights to the objects within a session and rely on social protocol to control access and turn taking. This method does not employ explicit conference membership control and explicit floor control mechanisms. The difficulties of relying on social protocol to control access primarily arise form the current inability of mult-user environments to capture the full range of personal interaction cues. This hinders the natural transmission of conversational floor control from one individual to another.

Secondly this does not allow for any form of control over who has access to the objects within a session. The current version of the MECCANO tools for instance does not allow for explicit knowledge of the members of a session and therefore is unable to provide explicit control over access to the objects in a session. While the tools allow control of membership participation through secure conferencing mechanisms this only provides an either or solution. A user is either allowed to participate in the session, and then has equal access to all objects in the session or they are denied access to the session at all.

In establishing floor control mechanisms a system needs to be able to control the level of simultaneity to support and the granularity at which to enforce access control [Schooler, 487]. The level of simultaneity determines the numbers of active users which can participate in a session at any given time. Simultaneous mechanisms should also control which users can be active and which can be passive. The granularity of access control is the level at which access to the workspace is controlled. In a shared text editor for instance this can involve controlling document access at either the word level or paragraph level [Schooler, 487]. I.e. Can a users access to editable text be controlled word by word or paragraph by paragraph, and can the system control which blocks of text are editable by which members. This is currently one of the limitation in Multicast based conferencing as this level of control, is difficult to achieve.

2.6 Multimodal communication

Perhaps the most notable issue facing collaborative applicasitosn is the handling of Multi-modal communications. In order for a system to be effective , it needs to be able to deliver natural interactiosn betwenne the participants. This requires the abilty to incorprate recrete the multi-modal communicatison patterns of individual participants.
The primary characteristic of face to face conversations is that the synchronization between participants occurs naturally. The ease with which this is accomplished is largely facilitated by the use of communication channels such as intonations of speech, hand gestures, facial expressions, body postures, gestures and particularly eye gaze. In order to implement successful tele-educational interactions therefore the tools must be able to capture the subtlety of the various modes of communications which individuals commonly use.

A further difficulty is that in general communication tends to decrease in efficiency as the number of participants increases (Preece, et al 179). This arises from the difficultiy people have in managing the increased amount of co-ordination required by multi-participant interactivity. In short people are generally poor at multitasking attention. In typical face to face collaborations, a number of social protocols are implemented in order to cope with this situation and to facilitate communication. These ranges from formal methods such as rasing hands to informal methods such as body gestures, or auditory cures such as throat clearing. In general these social protocols tend to work relatively efficiently largely due to the shared familiarity of the groups with the protocols and because of the close physical proximity of groups members which allow for the immediate and natural recognition of these cues. However in networked collaborations the facility of an immediate response is removed, as are the majority of physical cues which individuals depend upon. For this reason the audio and video channel which is restricted typically to facial display, tend to carry the burden of communication.

2.6.1 Video usability

Tang and Isaacs have undertaken an evaluation of the role of video in collaborative scenarios by examining groups that already had a pattern of working together [Patrick, 17]. In general Tang and Issacs found that users strongly preferred interacting in collaborative environments which contained video links to those which did not [Patrick, 17]. Users found that the video channel proved to be useful for interpreting long pauses and for providing access to body gestures which are used to facilitate interaction between people [Patrick, 17]. They also found that gaze awareness was relied upon to attempt to determine when a user was paying attention to whomever held the floor. [Patrick, 17]. While Tang and Isaacs study did not find a significant difference in task performance when using a video channel, they did observe that remote participants who did not have a video channel reported difficulties in mutual understanding because the users were not sure they were being understood [Patrick, 17].

This would indicate that the primary advantage of video channels becomes apparent when the task being undertaken is communicative in nature. Or largely relies on communication as part of its task. Tasks like co-editing a cad drawing or development of a software program where the completion of the task rely on video or textural communications may not receive large benefits from a video channel. However tasks such as seminar attendance and language learning which tend to depend more on personal interactions may well find a video channel indispensable to effective communication.

2.6.2 Eye contact

One of the current difficulties with Video conferencing applications results from poor eye contact facilities. The limitations imposed by bandwidth restrictions which result in frame rates typically between 6-8 frames per second combined with the smaller screen size results in a video image which makes it difficult to clearly establish adequate eye contact to enable meaningful interactions at this level.

In multi participant interactions the ability to control the floor largely relies on the use of eye contact. Hannes has demonstrated that in typical face to face communications average users spend almost half of the time looking at the speaker, supplementing the auditory information. In seminars situations and during conferences a typical speaker spends less time looking at the listener and will typically make eye contact when they are either expecting feedback, or attempting to emphasis certain points by assuring attention.

The importance of this of course varies depending on the type of event in which participants are engaged in. Seminar type broadcasts for instance depend less on direct personal interaction through eye gaze contact then does informal video conferencing applications or synchronous educational application. In general the greater the formality of the interaction the less users are required to rely on eye contact to determine when they should talk or perform some task. Strict floor control is therefore one solution to compensate for current limitations in eye contact facilities. However in most synchronous tele-educational situations there will be some need to allow for informal communications between participants. By assessing the demands for various situations, systems can be modified in the delivery of material in order to either maximize or minimize the clarity of a video signal.

2.6.3 Percieved quality

One difficulty in delivering video in a conferencing situation is the range of tolerance amongst users regarding the level of acceptable video quality. Some users have indicated that frames rates of 6 to 8 fps are acceptable. In initial studies undertaken at Hewlett Packard a small percentage of users have indicated that they are not unduly bothered by the quality of the video images at these frame rates. While they feel that better frames rates would be desirable, they generally find the video at these rates to be usable. Others however have indicated that they find video displayed at this rate to be highly distracting and would rather not have any video at all if it is below a certain level. This level seems to be around 15 fps, which is the rate at which the video quality becomes good enough to allow for reasonably natural communications between participants. These initial results would seem to indicate that there is to some degree a subjective nature to the assessment of video quality which needs to be considered in the design of any video conferencing or networked educational system.

This situation points out one of the difficulties with video transmission in that the acceptability of the image is not solely determined by the application itself but largely depends on the supporting infrastructure, which is largely beyond the control of the application. VIC for instance provides a reasonable clear video transmission of typically 6-8 fps at a sufficient resolution to make identification of features acceptable. Yet eye contact is still largely inadequate due to factors beyond those controllable by the video application itself. To a large extent therefore the primary limitation with video application lies in the supporting infrastructure and not in the application design.

One such limitation is that of camera placement. Typically cameras are mounted on top of monitors or to the sides. Users have to look at the monitor to see the application rather then the camera which subsequently makes eye contact sporadic and often nonexistent. This problem is particularly difficult to resolve as it arises from physical limitations that are unlikely to be solved in the short term. Therefore even with ideal bandwidth conditions, and application design, users will need to accept that eye contact in conference scenarios will not be as natural as in personal interactions.

2.6.4 Audio usability issues

In assessing the use of audio users tend to be more agreed in the requirements for usable audio. One of the current limitations with video conferencing systems stems from the variable quality of the audio channel. It is clear that for users at this stage, audio is the primary factor in insuring that effective communication between participants is achieved. Current tests being undertaken at Hewlett Packard examining the usability of different toolsets for the delivery of French Language lessons over the Internet, have shown that at the current level the general quality of the audio channel has been sufficient to deliver effective conferencing, and educational interactions over bandwidths at ISDN levels. While application like Microsoft's Netmeeting introduce some delays in audio transmission, and some breaking up of audio signals, the underlying structure is still adequate for providing suitable communication for teaching language courses at the beginner and advanced level. While the Video quality has been variable in the acceptance of its quality, the audio channel has generally proven sufficient for teachers and students to understand each other at a fairly advanced level of French. However at very advanced levels where quite subtle pronunciations in the language are being interrogated the current quality of the audio channel is insufficient. This would seem to indicate that in generalalized tele-educational situations the audio quality is sufficient. However in situations where the ability to detect and respond to subtle auditory cues becomes important the current audio quality may be insufficient. Again the limitations in this area are likely to be resolved by improvements to the network bandwidth, and Qualtiy of service schemes.

However a remaining problem, as with video is the difficulties of negotiating interactions in real time between participants of greater then 8 to 10. As the number of participants in a group grow dependence on communication channels not captured in current conferencing scenarios also increases. These initial observations would seem to suggest a need to limit real time participants in a tele-educational applications to smaller sized groups, or to establish a strict floor control policy. The HP virtual classroom, for instance has implemented such a policy which appears to function with a reasonable amount of success. Participants in a class must signal their desire to have the floor by the electronic equivalent of raising their hand. This enables larger groups to be able to be formed for the delivery of educational material. An additional feature of the Virtual classroom is the ability for participants to open private text based dialogues between themselves. This enables participants to in effect pass notes to each other during lessons. The immediate advantage of this is that it would enable working groups to break into smaller group to discuss amongst themselves a specific problem, and then return to the larger group to share the results of their collaboration. In fact this ability generates an advantage over real group interactions, as the communication between participants does not interrupt the communication between members of the larger group.

2.7 Shared workspace management

A basic requirement of conferencing tools is the ability to use and interact with media other than video and audio. Collaborative education environments, seminars, or colaborative work sessions require the ability to share documents, graphics files, or even programs. The requirements in this area generally involve issues of access control, document management, and shared environment co-ordination.

2.7.1 Shared environment co-ordination

On a initial level multi user environments require at some level a sense of shared context. This would require the adaptation of measures to enforce a basic common view and shared actions amongst the participants. This might involve causing all participant windows in a shared whiteboard to scroll when some other participant does. However collaborative environments also need to facilitate the maintenance of privacy and individual control over the workspace. At a basic level users who are sharing a document may require a view which is not only common to all users in the session but one which also allows for individuals to make personal notes and alterations to the document which affect only their version of the document, without these comments being viewable by the other members.

2.7.2Access Control

Dourish identifies the avoidance of conflicts within collaborative environments as one of the primary requirements for effective collaboration. Such conflicts may arise when two users attempt to access and change the same object. The primary essence of conflict management is to guarantee that any change users make to shared data will not lead to a loss of data integrity or to the synchronization of data. (Dourish , 56)

One of the difficulties identified in this area is the limitation in transferring and sharing documents over the video conferencing systems. This situation results from the diverse range of file formats that participants employ. Currently the only standard format which all applications can transfer between participants is standard ascii text files.

One solution to this is to develop scenarios which enable single user applications to be made collaboration transparent. The user can therefore continue to use familiar applications which can be used in either standalone or network mode. Ideally such a system would be able to transparently share specific programs such as a spreadsheet program or presentation package. A fully transparent application would ideally be able to then share the content of their windows with other participants in the meeting. This would be easier to accomplish in a centralized approach as all participants would be running an instance of a centralized program, which had access to and control of the display of each participants instance of the application [Schooler, 489]. One version of this approach is Netmeeting which allows users to open and share various applications on their desktops with other users in the conference. However as mentioned this causes severe loads on the network.

A different approach is to use a program which is designed specifically for collaboration, and which can import documents which it then shares amongst the other participants. One example of this is the shared network text editor (NTE) used in Meccano conferences. NTE is typically used to initially display the agenda for the meeting. Attendees to the meeting edit the agenda as they join adding their names to the list of participating members. As the meeting progresses attendees can insert comments to specific sections of the agenda. This acts as an impromptu whiteboard, where comments can be stored and added to the meeting minutes, key points can then be highlighted and modified. The individual attendees can then save individual copies of the NTE text file to their personal machines for later retrieval and reference. However because NTE operates in a replicated architecture there is no method for storing a centralized copy of the document which members could open later, change and save those changes so that all other members would see those changes if they were to open the document for their own viewing. Further NTE is constrained to sharing text documents.

One solution is using a centralized server which stores all documents in the conference. These documents are then made available to the various members of the group through a centrally controlled application interface. In Placeware this is a Java based client. Placeware allows whoever controls the floor to upload a Powerpoint set of slides and display them to the members of the group. The presenter then can assign to the members of the group permission to edit the document if he wishes. All member of the group see the same document and any changes to this document. After the meeting is over the changes can be saved to the original document and be reopened at a later time for re-editing by the group. This obviously has huge benefits for collaborative work scenarios and for educational based sessions. Currently this approach is the most useful method of enabling collaborative working, and document editing. However it does have the limitation of tying users into a proprietary server based conferencing solution.

2.8 Scalability

A primary requirement of collaborative systems is the ability to scale to varying group sizes and demands. A collaborative environemtn should not suffer any usability constraints due to traffic problems or network conditions despite the number of users access a conference. This should meean that ideally the performance quality should be the same wheterh there are 10 participants in a conference or if ther are 2. The advantage of the MECCANO tools and the IP multicasting architecture is that it is able to reliably scale to varying group sizes.

There are however realistic limitations to the number of participants in any desktop video conferencing situation arising from the limitations of desktop real-estate and of the cognitive load on a user to cope with an excessive number of windows. As the number of users in a conference increases the requirements on a user to manage the windows, and more importantly the interactions with and between the other participants greatly increases. One attempt to address this problem within the MECCANO tools is the use of voice switched windows within Vic (see section 2.3.4). This enables the user to more effectively manage the focus of interaction and activity within the session.

Equally important may be the design of systems which are able to adapt or be modified in the delivery of the differing media to specific situation or user demands. In an educational environment users machines can vary widely in their configuration and capabilities. Toolsets which are unable to accommodate a range of users skills and experience, as well as a range of machine capabilities will exclude large parts of a learner base from accessing its material. For this reason a primary requirement for any set of tools will be either the ability to scale to different user requirements or one which is able to operate on a minimal amount of resources or user skill. Current limitations within the various toolset arise primarily from weaknesses in this area. The Berkley mash toolset (http://www-mash.cs.berkeley.edu/mash/index.html) for instance while it attempts to provide for a broader usability base by incorporating the delivery of its material through a web interface, demands of the user a good deal of expertise in the use and configuration of scripting tools such as TCL/TK. And delivers sporadic performance, and stability.

The MECCANO tools currently cover a range of levels of complexity for setting up and installing the tools that are acceptable for beginning users to those that are more suited to expert uses. In addition a primary advantage of the tools over other approaches is the broad range of supported platforms. It is possible to install and run the various tools on a number of Platforms such as, Linux, Windows, Sun Solaris , IRIX and freeBSD. The easiest system configuration option is the Shrimp and ReLate packages which enable a user to implement a single install routine for the full range of the tools. Alternately users can choose to install individual tools, such as Vic, Rat, , Freephone, or NTE and use different versions which will all inter operate with each other. It is for instance, not necessary to have the latest version of Vic installed in order to make use of the latest version of RAT which has additional features that a user may want. This makes the tools accessible to a broad range of users increasing the usefulness of the toolset as a whole.

2.9 Venue Agility

Venue agility is the ability of the collaborative tools to be used for a variety of scenarios [Schooler, 486]. Because collaborative environments contain a number of different requirements even in the same session type it is desirable for the application being used to be flexible enough to adapt to various session requirements. A collaborative environment which is used to deliver educational material, may need in some cases to record, access and play back sessions, or to access pre recorded seminars, or other video material. It may also need to enable the sharing of applications between users or to allow users to move between synchronous and asynchronous modes or to move from a stand alone usage to working in a multiple group scenarios.

In situations such as this applications which are designed for very specific types of conferencing scenarios are likely to prove inadequate. This is one of the key advantages of the MECCANO tools current architecture, in that their flexibility allows them to be adapted to varying scenarios. The Pipvic2 project at UCL for instance is using them in the delivery of language courses. The University of Calgary in conjunction with a number of Canadian universities has also used the tools in the delivery of distance education programs. While Brims and the Internet Research Institute located at Hewlet Packard Laboratries in Bristol have used the same set of tools for the transmission of seminars and for use in conferencing. In addition the free availability of the source code (the tools are written in TCl/TK) makes it possible to customize the applications for specific purposes. In contrast typical bespoke conferencing toolkits such as Placeware, NetMeeting or most current online educational systems lack this level of flexibility.

The benefits of this model for the delivery of tele-educational applications is that they can feasibly incorporate a variety of materials in various media and deliver the material in a manner that will be able to scale to various participant group sizes. As well the material can be delivered in either synchronous or asynchronous time frames. That is users can either view the material in real time, or can access recorded sessions for playback at a later time.

2.10 Session Security

At some level initiating a collaborative scenario, whether conferencing based, or educational requires the ability to implement security policies. Ideally this security should be scalable to varying levels of access. i.e. Does a user have access to fully participate in a session, or to just watch, can they have access to edit all documents in the session, or can they only edit specific objects, or documents.

The MECCANO tools have implemented a secure session facility through the use of encryption of the data streams. This allows for the announcement of secure sessions, and for these sessions to be initiated without uninvited third parties accessing the conference. Currently the Mbone tools offer only on/off security measures. Either a member is allowed access to a session and therefore has the same level of access as all other members, or they do not have access. While this works is a reasonable approach it lacks the flexibility which may be required for educational or seminar style broadcast where it may be desirable to open the session to a specific group of people, but only allow some of those participants the ability to access, and edit objects in that session, such as a whiteboard, The ability to accomplish this would require the ability to monitor and know the nature of the participants, a feature which is currently lacking within the multicast infrasructure.

2.11 Session Recording

While this is may not appear to be a primary requirement of an informal conferencing scenario, it certainly is a requirement of educational and seminar style scenarios. The ability to record tutorial sessions, or the non synchronous delivery of seminars, or course work, is a crucial aspect of an collaborative learning environment. Whether this is used for later review by students or for assessment purposes by tutors. It is a feature which should be available to the system. The UCL development of MMCR is one attempt to address this issue and is typical of such recorder/players [Kirstein, et. al. 47].

MMCR is a system specifically designed for recording and playing back multicast multimedia conferences over the Mbone. It is based on a client server architecture, and consists of the graphical client front end and a recording and caching application which resides on a server. In this situation a server operates as the point of contact for recording , browsing and playback of sessions. To record the media streams the recorder does not have to be an active part of the conference. It listens to the specified Multicast groups and collects the data, with the streams being stored on the server for later retrieval [Kirstein, et. al. 47].

This situation, offers distinct advantages for educational uses in that it can facilitate the implementation of recording and playing back of lectures, seminars, and classroom sessions for later evaluation. The advantage of storing data on a per source basis also means that users can playback only the streams they are actually interest in and ignore those they are not.

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